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THE PENNSYLVANIA STATE COLLEGE

SCHOOL OF AGRICULTURE

Agricultural Experiment Station

Late blight. Its usual appearance on foliage before vines are killed.

POTATO DISEASES

C.R. ORTON

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THE PENNSYLVANIA STATE COLLEGE
SCHOOL OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION

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BULLETIN No. 140.

The Diseases of the Potato

BY C. R. ORTON.

INTRODUCTION.

The potato is one of the most important crops in Pennsylvania, being surpassed in total value only by hay, corn and wheat in the order named. According to statistics collected by the United States Bureau of Crop Estimates, Pennsylvania raised 20,160,000 bushels of potatoes in 1915 or nearly 6 per cent. of the total yield for the United States. In total yield of potatoes for a five-year average, Pennsylvania ranks sixth among the states, being surpassed by New York, Michigan, Wisconsin, Maine, and Minnesota in the order named. At 75 cents per bushel, which was the average selling price in Pennsylvania, December 1, 1915, this crop was worth $15,120,000.[1]

The season of 1915 was favorable for a good yield until about August first, when the "late blight" appeared generally throughout the State. The disease became epidemic with the result that the average yield in the State was reduced to 72 bushels per acre which is considerably below the ten-year average of 87 bushels.

A conservative estimate of the loss to the potato crop from diseases is 20 per cent., based on records kept on the occurrence and extent of plant diseases in the State by the Department of Botany. Figured on the average annual crop, this loss amounts to about 4,500,000 bushels annually, and it is even greater when the shrinkage caused by decays in storage is taken into account. Such losses are largely preventable, and this bulletin is designed to present to the potato growers of Pennsylvania more complete information concerning the nature and control of these diseases.

ORIGIN AND SPREAD OF POTATO DISEASES.

A comparatively few years ago there were only about three well known diseases of the potato in the United States, viz., scab, early blight and late blight. At the present time there are over

[1] These figures are taken in part from U. S. D. A. Monthly Crop Report 1; No. 8. 1915.

twenty diseases described, not including the numerous troubles due to insects. The potato grower may be excused for being discouraged when he has annually to face this serious condition, which has no doubt caused many to abandon the industry except for the home table.

Where do these diseases originate and why have they increased so rapidly in the last few years? The origin of all these diseases is not clear; it is known with certainty that some of them existed as diseases of the potato at the time it was discovered in the Andean Region of South America. The "late blight" was most certainly brought into Europe from South America. Other diseases, which have been known for a considerable period, quite likely have a similar origin. It seems that the appearance of several diseases only recently known, i. e. stem-rot and black-rot, can be explained on the hypothesis that the organisms causing them are normally soil inhabiting and that they have become parasitic gradually through changes in conditions which have perhaps both weakened the host and stimulated the fungus to obtain its food from living plants rather than from those which have died. That these conditions are taking place continually but gradually seems certain and is another argument for longer crop rotations.

There are several explanations for their rapid increase: 1. This country has been importing from foreign countries large amounts of potatoes in recent years, and with these importations there have come in, to a great extent, the diseases which are now threatening the industry so seriously. 2. The development of the South as a source of early potatoes, and the necessary shipment of seed tubers from northern regions for this purpose. 3. The careless practice of using table stock for seed purposes has also led to a considerable spread of diseases. 4. The improvement and development of varieties of potatoes and their exchange throughout the country has spread diseases to some extent.

Most of our potato diseases seem to have come from European countries which have in the past furnished us large quantities of potatoes annually. Within the past few years there have been introduced some serious diseases which have brought us to take decided measures against the importation of potatoes into the United States except under strict quarantine regulations.

THE FEDERAL QUARANTINE ACT.

On account of the many recent importations of plant diseases and insect pests Congress passed the Simmons Bill which became the Plant Quarantine Act August 20, 1912. This act provides for the regulation of importation and inspection of practically all plants and plant products, and it has already proved of considerable value in keeping from our borders several serious diseases and in controlling the spread of some previously introduced. This last result has been effected because the Act gives the Federal Horticultural Board the right to control the interstate exchange of plants and plant products when the situation demands it.

CONTROL METHODS.

Aside from the question of quarantine the efficient control of potato diseases on the farm depends upon carrying out a *system* of management and treatment which is designed to eliminate and prevent the chief troubles, not to cure them after they have appeared. The idea of curing parasitic plant diseases is a common fallacy, for no practical methods of restoring normal health to the plants have yet been devised, nor is it likely that such methods will be soon devised.

There are four important factors to be considered in the prevention and control of potato diseases. These are: 1. Soil relationships; 2. Seed selection; 3. Seed disinfection; 4. Spraying. Not one of these factors can be omitted if the grower is aiming at high yields and freedom from disease.

SOIL RELATIONSHIPS.

There are five matters of importance which may be considered properly under this head.

(a) Selection of Soil. Potatoes usually do best in the lighter loams. Clay soils which become sticky and plastic during wet weather, and cake during dry weather, are to be avoided. Low lands or lands not well drained should also be avoided. The reasons for avoiding these soils not only hinge on the question of productivity but also upon the severity of "russet scab" in such locations. Soils strongly alkaline should also be avoided on account of their tendency to promote the "common scab."

(b) Preparation of Soil. For the best results in growing potatoes a good seed-bed is indispensable. *Large yields* are never uni-

formly produced in a poorly prepared seed-bed. Fall plowing is to be recommended and thorough disking and harrowing are essentials.

Lime, wood ashes, etc., should not be applied in large quantities to land just previous to growing potatoes. These materials tend to make the soil alkaline and thereby favor the growth of the common scab. If the land is in moderate need of lime, apply it after the potato crop. If the lime need is great, lime the crop preceding potatoes, avoiding excessive dressings, so that the soil may not be made alkaline for the latter.

(c) Fertilization of Soil. If fresh stable manures are to be used they should be plowed under in order to facilitate their decay and lessen the likelihood of the manure making the soil alkaline and thus stimulating scabbiness at a critical time, as it frequently does when applied after plowing, and then worked in with the disk or harrow. Thoroughly composted stable manures are safer to use as a surface dressing.

Probably better results with potatoes are regularly obtained by plowing in cover-crops, such as legumes, rye, etc., and using commercial fertilizers for reinforcement.*

(d) Cultivation of Soil. The potato crop requires all the available food it can obtain under normal conditions. The plant takes this food up in soluble form and consequently a considerable amount of water is necessary for proper growth. In dry seasons much trouble is encountered with "tip-burning" and other evidences of the lack of water. Avoiding high-ridging will help, but more important is the frequent shallow cultivation of the soil up to the time when the tops pretty well cover the ground. A dust mulch results from this surface cultivation and conserves the necessary moisture in the soil.

The eradication of weeds is an important factor in the control of many insect pests and certain of the fungous diseases.

(e) Crop Rotations. In so far as certain potato diseases (those caused by organisms living a part of the time in the soil) are affected by crop rotations, it seems proper to discuss rotations under soil relationships.

* For a more detailed discussion of cover-crops and fertilizers for potatoes the reader is referred to Pennsylvania State College Agricultural Extension Circular No. 45.

It is a well known fact that many insect enemies of plants and certain bacterial and fungous parasites live from season to season in the soil, either upon various plants or decaying vegetable matter, or by simply lying dormant in the soil until their chosen host is grown again in the same soil. If the proper host plant is not returned to the soil for four or five years or perhaps longer some of these parasites die out, and it is perhaps chiefly on account of these habits that long crop rotations are so beneficial in controlling some potato troubles.

A three-year rotation is followed frequently in Pennsylvania, but in sections where "stem-rot," "wilt," "black-rot," the "stalk-borer," etc., are prevalent a four or five-year rotation would be preferable. What such a rotation should be is largely a matter for experiment by the grower for his particular conditions.

SEED SELECTION.

Seed selection with potatoes is for three purposes: 1. Increase in yield; 2. Greater uniformity in size and shape; 3. Greater freedom from disease and greater resistance to disease. The same methods are applicable in each case. There is little doubt that seed selection is one of the most important phases of the potato industry and no one can afford to grow potatoes on a commercial scale without practicing selection.

Potato breeding is quite a different matter for it necessitates the cross fertilization of varieties, the growing of seedlings from seeds of the resultant crosses, and the subsequent development of new varieties. Considerable knowledge and skill and much time are required for this work and it can be practiced only by the few, while selection may be practiced by anyone. Furthermore, the results obtained through breeding, while they may be of great importance, are slow in coming, while the results from selection are quickly gained.

The old method of selecting good-looking tubers from a bin of miscellaneous potatoes will never produce the results which systematic methods give. There are two such methods in common practice either of which will produce the desired results. These are the "tuber-unit" and the "hill" method.*

* For further information on methods of selection, see Extension Bulletin No. 45.

Disease resistance should not be lost sight of in following any line of field selection. The selection of disease-free tubers at planting time is of *great importance* and should be carried out independently of field selections of any kind. This method of selection is of the utmost importance in eliminating "wilt," "stem-rot," and other diseases caused by internal parasites.

SEED DISINFECTION.

The primary purpose of seed disinfection is, of course, the destruction of the organisms causing scab and blackleg, and even though these diseases are not in evidence, it is undoubtedly worth the expense entailed to treat the seed with either formaldehyde or mercuric bichloride solution. There are usually present on the surface of potatoes many fungous spores and perhaps other organisms which might be a source of disease. The cost of materials for the treatment should not be more than two cents per bushel and the added protection afforded is worth much more. For the russet scab and silver scurf, the mercuric bichloride treatment is more effcient than the formaldehyde treatment. The only objection to the use of mercuric bichloride is the danger from its storage in buildings where there is a possibility that persons or animals may take it internally, as it is a deadly poison when so taken. When stored it should be conspicuously labeled "poison." The treatment in brief is as follows:

Mercuric bichloride (corrosive sublimate).. 4 ounces
Water .....30 gallons

Soak the seed tubers one and one-half hours in this solution and spread them in a clean place to dry. Metal containers should not be used for this treatment, for the corrosive sublimate corrodes them rapidly and the solution loses its efficiency.

The formaldehyde treatment is more frequently used and for "common scab" and "blackleg" is as efficient as the mercuric bichloride. It is as follows:

Formaldehyde (40% solution)..... 1 pint
Water .....30 gallons

Soak the seed tubers two hours and spread them out to dry in a clean place.

The disinfection of a considerable quantity of tubers is most conveniently and rapidly done by setting several barrels half filled with the solution on a platform so that after the potatoes have been in the solution the required time the formaldehyde may be drawn off through a faucet in the bottom of the barrel and immediately poured into other barrels containing tubers to be disinfected. The solution may be used five or six successive times without materially lessening its efficiency, provided it does not stand over night between such treatments.

Those growing potatoes on a large scale may find it most convenient to use the formaldehyde gas treatment, if they have a suitable room or cellar which can be shut up tightly. This method is inexpensive and rapid, but there is some danger of injuring the tubers under certain conditions pointed out by Stewart and Gloyer[2]. They recommend that the following method is safe, provided there are 167 bushels of potatoes per 1,000 cubic feet of space, or the proportion between the quantity of potatoes and space is approximately this. With a much smaller quantity of potatoes in the same space the gas might produce a pitting injurious to their germination if it affected the eyes of the tubers. Severe pitting is most likely to result when there are less than 100 bushels per 1,000 cubic feet of space. The gas treatment is as follows:

Formaldehyde (40% solution)..... 3 pints
Potassium permanganate ..... 23 ounces

This amount is sufficient for each 1,000 cubic feet of space. The permanganate should be divided into about three equal lots and each lot placed in an open metal dish. The formaldehyde is then divided accordingly and each part poured over the permanganate in such a way that they are thoroughly mixed. The room should immediately be closed tightly for about twenty-four hours or at least over night.

Tubers can probably be disinfected best in this way when they are in open crates, thus allowing free access of the gas to them. However, potatoes lying on the floor in piles are apparently quite thoroughly disinfected. They should not be in sacks when this method is used.

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[2] Stewart, F. C., and Gloyer, W. O., N. Y. Agr. Exp. Sta. Bull. 369. 1913.

SPRAYING.

The systematic spraying of potatoes was first begun by Jones[3] at the Vermont Experiment Station. His first results with Bordeaux Mixture were so satisfactory that workers at other Experiment Stations soon took up spraying and it was adopted generally as a regular practice. It is now certain that Bordeaux Mixture is the most efficient spray for potatoes and that spraying pays, provided it is thoroughly and frequently done.*

That Bordeaux Mixture is the most efficient spray for potatoes has been demonstrated many times and in many states, where every substitute on the market has been used for a comparison. The results show that home-made Bordeaux Mixture will, if thoroughly applied, increase the production from 50 to 200 bushels per acre. Bordeaux has two distinct effects on the potato. It protects the plant from the "early" and "late blights," and it stimulates growth and tuber formation.

How to Make Bordeaux Mixture.

Bordeaux is made of copper sulphate, caustic lime and water. The proportion for potatoes is 5 pounds copper sulphate, 5 pounds of caustic lime and 50 gallons of water. About 70 to 100 gallons of the spray are required to cover each acre of potatoes. If 100 gallons is the desired amount, place 10 pounds of copper sulphate in a loose sack and suspend in 10 gallons of water. As several hours are required to dissolve the crystals, that may best be done by preparing the mixture at night and leaving the crystals in the water until morning. Then add 40 gallons of water.

The caustic lime is placed in some receptacle and covered with enough water to slake it. As soon as slaked add water to make 50 gallons of the lime water.

The most important part of the process follows. Keep each solution thoroughly stirred. Have a large container covered with a fine strainer to receive the Bordeaux mixture. Two men are required to do the dipping and pouring thoroughly. Each should

[3] Jones, L. R., Vermont Agr. Exp. Sta. Rept. 4:131-138. 1890.

* This statement is based on the average cost of copper sulphate. As this bulletin goes to press we are advised that this ingredient is listed at about 10 times its normal price. It does not seem likely that present war prices will prohibit the extensive use of copper sulphate more than temporarily. At the present price it will cost for each application from $2.00 to $3.00 an acre more than usual.

dip out a bucketful from the separate solutions and pour them at the same time through the strainer into the container. This serves both to mix and to strain the solutions. The solution resulting from this mixture is Bordeaux which is of a milky blue color. It is then ready for application and should be applied as soon as possible. In case large quantities of Bordeaux are to be used it will pay to make up a considerable stock quantity of the lime water and copper sulphate solutions. A handy method is to have two tanks prepared and set on a platform high enough to permit the contents to be drawn out through a faucet into a third tank, or directly into the sprayer, if desired. The two solutions should be drawn out simultaneously and into a strainer in order to obtain a thorough mixture. Such stock solutions may be kept separately some time if covered to prevent evaporation. The two solutions should not be mixed except for immediate use, for the reason that the efficiency of the Bordeaux is partially lost by standing more than a few hours.

Lead arsenate, 6 pounds of the paste to each 100 gallons of Bordeaux, or Paris Green 1 pound to the same volume, should be added, to kill the insects feeding on the foliage.

When and How to Spray.

Spraying should begin when the plants are 6 to 8 inches high and at least three applications, preferably four to six, should be made at about two-week intervals.

The spraying should be thorough, as the plants must be covered with the fine mist in order to be effectively protected. A spraying machine which develops at least 100 pounds pressure is recommended. This should have for the later sprays two nozzles for each row, so arranged that a fine mist is thrown upon the leaves, thoroughly covering every one of them.

During the latter part of July and throughout August particular care should be exercised in spraying. As soon as it is noticed that the previous spray is no longer evident, make it the aim to apply the Bordeaux before the rains, for at this time of year late blight, if it appears at all, does so after the rains. By getting the Bordeaux on before the rains the plants are protected from infection by this disease.

POTATO DISEASES

The diseases of the potato may fall into seven classes according to their cause. One of these classes (6) contains several diseases the causes of which are yet in doubt.

1. Diseases caused by Slime Moulds.

The slime molds are an interesting group of living organisms which are probably closely related to both plants and animals. Only a very few of them attack plants and cause disease. Notable examples of those attacking plants are *Plasmodiophora Brassicae* Wor., the cause of the "club-root" of cabbage and other crucifers, and *Spongospora subterranea.*

Powdery Scab, *Spongospora subterranea* (Wollr.) Johns. This disease was introduced into North America only a few years ago. It was discovered in the United States by Morse[4] and Melhus[5], in 1913, in Maine. The seriousness of the disease in certain Euro-

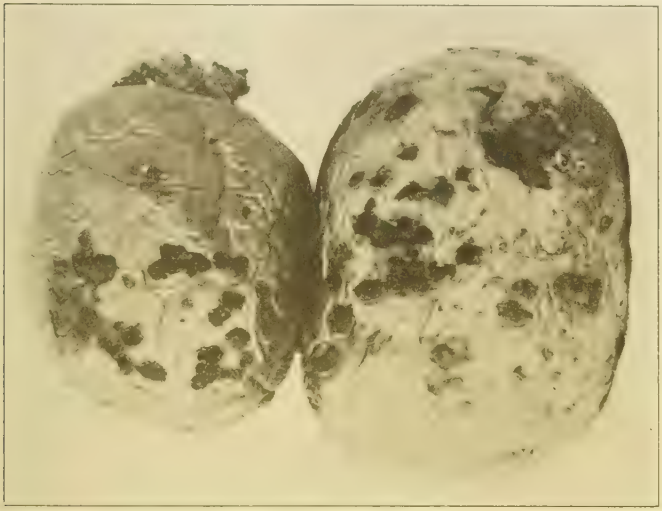

Fig. 1—Typical appearance of powdery scab.

[4] Morse, W. J., The Powdery Scab of Potato in the United States. Science 38:61-62. 1913.

[5] Melhus, I. E., The Powdery Scab of Potatoes in Maine. Science 38:133. 1913.

pean countries led to the Federal Quarantine on Maine potatoes grown in the infected regions. Extensive studies by government specialists have recently demonstrated that this disease is unlikely to be of serious importance except in certain northern potato sections and the quarantine has been removed. It seems now unlikely that it will become established as an important disease in Pennsylvania but if suspected cases are found they should be reported at once to the Experiment Station and efforts made to stamp them out.

Powdery scab may be confused with certain stages of "common scab" and "russet scab." It is characterized in the early stage by small, slightly raised blisters which later rupture and disclose the brownish masses composed chiefly of spore-balls. The ruptured skin of the potato rolls back in a characteristic manner which often serves to distinguish the disease from "common scab." Fig. I shows a well-developed case of powdery scab.

2. Diseases caused by Bacteria.

The bacteria are very low forms of plant life. Most of them are so small that only when they are magnified several hundred times under the microscope can they be seen. Bacteria are present everywhere in the air, water, soil, etc. Some of these bacteria are parasitic and cause well-known human diseases, such as typhoid fever, etc. Others cause animal diseases, such as "lumpy jaw of cattle." Still others are now well known to be the cause of plant disease. Several potato diseases have been attributed to bacteria in various parts of the world, but in the United States only three bacterial diseases of the potato are well known and of these only two are known to occur in Pennsylvania. In addition, "brown-rot" occurs in the southern States.

Black leg, *Bacillus phytophthorus* Appel. This disease usually appears early in the season, about the time the plants are six to eight inches high. Affected plants turn yellowish, wilt, and fall over or die. If pulled up and examined in the early stages a decayed seed piece is found and the stem from the seed piece from two to four inches upward is dark colored, as shown by Fig. II. Frequently, young tubers may form before the disease kills the tops and such tubers may grow to marketable size. The bacteria are apparently carried from season to season on such tubers which

may have a small decayed spot at the stem end. The disinfection of all seed tubers will control this disease.

Fig 2—Black leg. Note the blackened stem below. (From Maine Exp. Sta. Bull. 194. Courtesy W. J. Morse.)

Common Scab, *Actinomyces chromogenus* Gasp. This is probably the most common and best known disease of potato tubers, being widely distributed and frequently serious in many parts of the world. Turnips and beets are also frequently attacked by it in some regions.

The organism (*A. chromogenus*) causing common scab not only lives in the soil but also lives in the scab spots in the tubers. When it exists in the soil it is apparently able to attack the potato seriously only when the soil is alkaline.

The disease hardly needs description. It scarcely can be confused with "powdery scab" but may be with "russet scab," especially when both diseases occur together on tubers, as is sometimes the case. Common scab usually causes larger and deeper spots than russet scab and these spots frequently have a "target-like" ap-

Fig. 3—Common Scab. Both normal and pitted scab spots are shown.

pearance. Frequently the scab spots become deep and pitted. This condition appears to be most often due to various insects which feed in the infected areas. (Fig. 3).

Disinfection of the seed tubers is very effective in preventing common scab, when the tubers are the chief source of infection, but when the soil is heavily infected, as is apt to be the case if it is alkaline in reaction, then seed disinfection is not so efficient. Under this condition some soil treatment which will change the reaction from alkaline to slightly acid is to be recommended. Plowing under green cover-crops, particularly legumes, rye, or buck-

wheat tends to check the scabbing by reducing the alkalinity of the soil and makes a nearly ideal seed-bed.

Scabby potatoes should not be fed to animals if the manure is to be used as a source of fertilizer for potatoes. The organism survives the processes of digestion and is carried back to the field in the manure.

Fig. 4—Russet Scab. Showing the "black specks" which do not easily wash off. This is the resting stage of the fungus.

3. Diseases caused by Fungi.

Fungi, like bacteria, are also plants but are a step higher up the plant ladder. Like the bacteria they are present almost everywhere and are able to live under a great variety of conditions. The great majority of plant diseases are caused by fungi which are either strictly parasitic or partially parasitic. The strict parasites are not able to live and reproduce except on a living host. The partial parasites may be able to live for a time under saprophytic conditions on non living organic matter in the soil, etc. Some of these latter are our most important potato parasites, such as *Corticium*, *Fusarium*, etc. It is chiefly on account of these partially

parasitic organisms that crop rotations are so helpful in keeping some plant diseases under control.

Russet Scab, *Corticium vagum Solani* Burt. This fungus is a common inhabitant of most potato soils, as is attested by the almost universal presence of the fungus on potatoes wherever they are grown. (Fig. 4). This statement is not intended to convey the idea that the fungus causes a serious disease wherever it is found on potato tubers; on the contrary it usually causes serious damage only on certain soils and in certain seasons when weather conditions are favorable for its development.

The fungus becomes actively parasitic in wet or poorly drained soils and during seasons when precipitation is heavy. Various forms of the disease have been observed, the most important of which are the following:

1. The killing of young sprouts, even before they reach the surface of the soil. Undoubtedly the cause of poor stands many times on heavy soils.

2. The production of lesions on stems below the surface of the soil. This may result either in potato "rosette" or the formation of "aerial tubers."

Fig. 5—Russet Scab. Showing russeting and scabbing caused by *Corticium*.

3. Attacks on the roots, causing the production of large numbers of small tubers, frequently irregular in shape, called "little potato" disease. Sometimes confused with "curly dwarf."

4. Attacks on the tubers, causing a cracking and russeting effect upon the skin.

5. A serious scabbing of the tubers, (See Fig. 5). This last may be accompanied by some pitting.

Inasmuch as the fungus is parasitic on many other plants besides the potato, the rotation of crops is not likely to check the disease materially. Drainage and the avoidance of heavy soils for

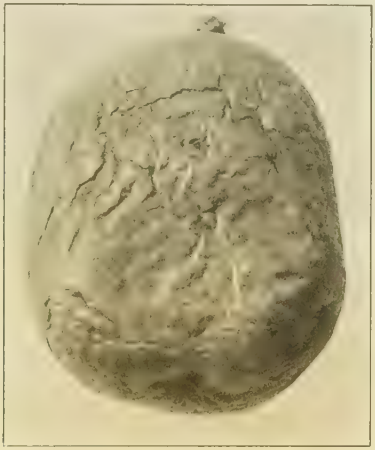

Fig. 6—Silver Scurf. Characteristic shriveling of diseased tubers which takes place in storage.

potatoes are of more importance. In soils relatively free of the fungus the disinfection of seed tubers with corrosive sublimate will prevent any serious trouble with this disease.

Silver Scurf, *Spondylocladium atrovirens* Harz. The disease of potato tubers known as "silver-scurf" is prevalent throughout the East. Fortunately it is not very serious. It causes some loss to tubers in storage by destroying the skin which permits considerable loss of water and consequent shriveling. (Fig. 6). It may be most easily detected when the tubers are washed. The irregular brownish areas on the skin turn silvery when moistened.

Experiments in seed disinfection by the usual methods have not proved particularly efficient. Seed selection seems to be the most practical method of treatment. Seedsmen who find this disease detrimental to the sale of their seed tubers should practice long rotations and selection for resistant strains.

Black Rot, *Fusarium radicicola* Wollenw. This disease, which is known to the potato growers of Pennsylvania as "black rot" or "black head," is caused by a soil fungus which occurs locally in

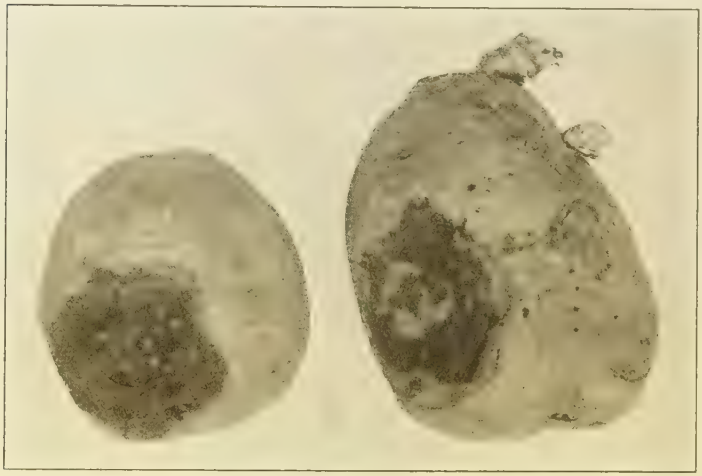

Fig. 7—Black Rot. Showing the typical appearance on surface. Compare with Fig. 9.

certain parts of the United States. However, in California and other western States, according to Carpenter[6], the usual form of the rot caused by this fungus is known as "jelly end rot." Apparently the differences in soil and weather conditions existing in different parts of the country may account for the variation in forms of the disease. The soft rot form (jelly end) has never been seen by the writer in Pennsylvania.

Black rot is quite serious and prevalent in the eastern part of Pennsylvania, the writer having seen in several instances from 10

[6] Carpenter, C. W., Some Potato Tuber Rots Caused by Species of Fusarium. Jour. Agr. Research, 5:183-210. 1915.

to 25 per cent. of tubers in storage affected with the disease. Apparently the disease is rarely noticeable at digging time but develops chiefly during storage. At this time it is characterized as a sunken, blackish, leathery area, varying from the size of a dime to a half-dollar. (Figs. 7 and 8). Under Pennsylvania con-

Fig. 8—Showing appearance of cut tuber affected with black rot. Compare with Fig. 10.

ditions the disease may appear on any part of the tuber (i. e., sides or ends). It seems likely that a wound is necessary for the entrance of the fungus, although some cases have been found where infection seemed to have taken place through lenticels (the small openings through the skin of the tubers).

Control measures necessitate the rotation of crops, the rejection of all diseased tubers for seed, and careful attention to storage conditions.

Stem rot, *Fusarium eumartii* Carp. The disease known locally under the name of "stem rot" is a serious one in Pennsylvania, particularly in some of our best potato growing sections. The disease was first called to the attention of the writer in the fall of 1913 when badly stem-end dry-rotted tubers of Heath's Medium Late Surprise variety were sent to him for identification of the disease. Apparently the disease was new and specimens were

submitted to the Bureau of Plant Industry, Washington, D. C., where a special study of similar diseases was being made. The results have been published by Carpenter[6] who described as a new species the fungus causing this disease. More recently the disease has been found in New York and reported on by Haskell[7].

In the field the disease is rather difficult to detect. It most closely resembles the symptoms of wilt and on digging affected plants a slight decay is found at the stem end. This is easily overlooked and the affected tubers are usually carried to the cellar

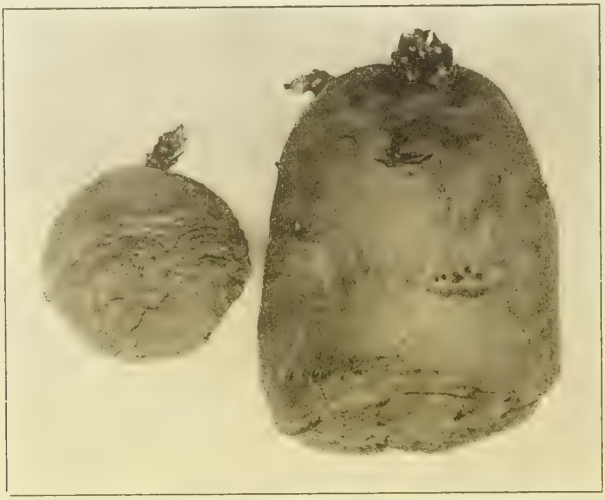

Fig. 9—Stem Rot. Tubers as they appear in storage about midwinter or later.

in this condition. Decay proceeds rather slowly but by midwinter is very conspicuous. At this time the diseased tubers are from one-quarter to one-half decayed. The disease is so serious in some cases that 25 to 50 per cent. of the tubers in storage may be badly affected with the rot in various stages. It seems probable that a large per cent. of these stem-rotted tubers were infected when placed in storage.

In studies made by the writer it is evident that "stem rot" may follow "wilt," and Carpenter[6] supports this view. Haskell,

[7] Haskell, R. J., (Abstract) Phytopathology 6:106-107. 1916.

however, believes the bundle discoloration is caused by the same fungus which produces the stem-rot. The vascular bundles are generally browned in advance of the decay and it seems certain that this discoloration is in some cases caused by the wilt fungus. This habit of stem rot following wilt infection may account for the greater severity of the disease in relatively dry, warm seasons.

Fig. 10—Cut tuber showing internal effect of stem rot. Compare with Fig. 8.

The disease may be distinguished from all other potato diseases common in Pennsylvania by the following characteristics: 1. Decay nearly always starts at the stem-end. 2. The decayed part shrivels slowly and becomes filled with a brown mass of dried pulp composed of dead tissue. (Figs. 9 and 10). 3. In the final stages of decay the skin does not shrivel as rapidly as the flesh inside, so that a thin shell-like membrane remains which is filled with a more or less loose, pulp-like mass.

Control measures necessitate a longer crop rotation than is practiced in some of our potato sections. Potatoes should not be grown on the same land oftener than every four years and longer

rotations are desirable. Care must be taken that seed tubers for planting be very carefully selected. All tubers showing stem-end browning should be discarded.

Wilt, *Fusarium oxysporum* Schlecht. Potato "wilt," like "common scab" and "russet scab," is widely distributed in potato-growing sections of Europe and America. While the fungus has been widely advertised as a soil organism, yet the evidence at hand seems to indicate that its chief method of infection is through planting infected seed tubers. The fungus is an *internal* parasite which plugs up the vessels in the stem, roots and tubers, thus causing wilting, premature dying and great reduction of crop. (Fig. 11).

Fig. 11—Wilt. Yield from 10 wilted hills at left and 10 healthy hills at right. (Illustration by courtesy of C. F. Noll.)

The diagnostic characters of wilt are first noticeable in the field about four to six weeks before the crop should ripen. At this time affected hills show a slight yellowing of foliage and a strong tendency to wilt during the warm part of the day. In a short time the plants fail to recover and they die prematurely, often before the tubers are more than two-thirds grown. Fields have been seen in Pennsylvania where as high as 35 per cent. of the hills were diseased.

At the same time that the fungus is plugging up the water-conducting vessels in the stem and causing the wilt, it is also developing in the underground parts, growing out from the roots into the tubers, causing a browning of the vascular bundles ("ring discoloration") at the stem end. (Fig. 12). Here the fungus lives through the winter in a semi-dormant condition and such tubers, if planted, hand on the disease to the following crop.

The method of treatment to prevent serious loss by this disease consists chiefly in taking extreme care not to plant any tubers

Fig. 12.—Wilt. Showing the internal "ring discoloration" which may be detected only by cutting across the stem-end of tubers.

affected with "wilt." This selection may be made best when the tubers are being cut for planting. *Do not plant entire tubers without first clipping off a thin slice from the stem end* and noting whether "ring-discoloration" is present or not. If no discoloration is present the cutting has not harmed them for planting. If the tubers are browned, as seen in Fig. 12, discard them for seed purposes. Tubers intended to be cut for planting may be examined after the longitudinal cut is made. Any brown or blackish streaks extending inward from the *stem end* should condemn them for seed purposes.

As in the case of "stem rot" a long rotation of crops is desirable. The practice of "roguing," i. e. removing all wilted hills during the growing season, is used by seedsmen with good results and is to be recommended generally where home-grown seed is used for planting.

Storage rots, *Fusarium* spp. Several species of Fusaria are able to attack injured tubers in storage and cause considerable loss. They are chiefly semi-parasitic fungi which live in storage cellars and probably in the soil. The most common one in Pennsylvania is *Fusarium coeruleum* (Lib.) Sacc., which causes a characteristic wrinkled decay, as shown in Fig. 13. Numerous bluish-

Fig. 13—The common type of storage rot found in Pennsylvania. It follows some other injury or disease on the tubers.

white spots often appear on the decayed part. Storing under low temperatures appears to retard its development. The disinfection of all cellars before storing in the fall is to be especially recommended. If the storage cellar is tight the use of formaldehyde gas is the quickest and easiest method.

Early blight, *Alternaria Solani* (E. & M.) J. & G. Early blight is the only common *fungous* disease of potato foliage. It does not attack the tubers. On the leaves it causes brown spots which later develop concentric markings, giving the spots a "target" effect. (Fig. 14). Affected areas often fall out and a "shot-hole" effect

results. Frequently the spots are so numerous as to kill the foliage, and then serious loss to the crop results. Even when the

Fig. 14—Early blight. Note the "target" spots. (Illustration by courtesy of the Vermont Arg. Exp. Station.)

spotting is not serious enough to kill the foliage, maturity is hastened and the yield is low.

The fungus evidently lives over from season to season on decayed tops and perhaps other refuse. For this reason the practice of burning the old tops in the fall is to be recommended. Certain varieties appear to be nearly immune to the disease, and it may be desirable to select for planting such varieties or strains. Spraying with Bordeaux Mixture, if thorough and timely, will prevent this disease.

Late Blight, *Phytophthora infestans* (Mont.) deBary. No disease of the potato is more destructive than late blight in years when it is epidemic, as it was in 1915. This disease has been investigated more thoroughly than almost any other plant disease and yet the important question of how it lives over from one epidemic year to the next, under similar conditions to those existing in Pennsylvania, is not definitely known. Investigators are divided on the question. The majority perhaps believe it to be

carried from year to year on the seed tubers but not becoming epidemic except in certain years when the meteorological conditions are favorable for its spread. This explanation is plausible for more northern conditions, such as are found in Maine, Vermont, Northern New York, etc., but under Pennsylvania conditions, where no sign of the disease may be found for three to five years or more in succession and then a very destructive epidemic appears, this explanation does not seem to hold good. It seems more logical to suppose that with us the fungus passes the intervening period, in a resting condition in the soil, awaiting favorable conditions for its appearance.

Fig. 16—Late Blight Rot. Characterized by a brown water discoloration extending in from the skin.

However it may live over, the fungus unquestionably comes through the soil and infects first the lower leaves of the potato plant and from them gradually spreads over the foliage until the tops are killed if weather conditions remain favorable for its continued development.

The disease on the foliage is manifested by dark watery areas which may or may not develop rapidly in size according to the weather conditions. Upon the under side of these areas a frost-like mildew appears which is the fungus bearing its spores. (Fig.

15, front cover). These spores spread the disease not only to other leaves but they also fall to the ground, into which they are washed by rains, where they infect the tubers, thus causing the well-known rot always accompanying "late blight." (Fig. 16).

The meteorological conditions favorable to a development of late blight are not well known. Apparently they are: 1. A low soil temperature. 2. High relative humidity; and, perhaps,

Fig. 17—The typical uprolling of tips and margins of leaves as it occurs in "tip burn."

3. High soil moisture content. While the disease usually appears in seasons when rainfall seems to be excessive and temperature low, yet data collected by the writer[8] seem to show that these factors only indirectly affect the appearance of the disease.

The question often comes up with regard to the advisability of planting seed tubers from a crop of potatoes affected with late blight. Care should be taken not to plant any tubers visibly affected with the disease; little danger, however, really exists in

[8] Orton, C. R., Meteorology and Late Blight of Potatoes (Abstract) Phytopathology 6:107. 1916.

using seed from such sources under Pennsylvania conditions, for even were some affected tubers planted an epidemic would not result unless certain meteorological conditions such as mentioned above should exist the next season, an unlikely occurrence.

Fortunately we have an almost sure preventive for late blight. Bordeaux Mixture, if applied timely and thoroughly, will prevent the disease by killing the spores which lodge on the leaves and cause infection. See spray direction, page 12.

4. Diseases caused by Unfavorable Weather and Soil Conditions.

Tip Burn. The common trouble known as "tip burn" is frequently confused with "early" and "late blight." The absence of the "target" spots, however, will distinguish it from the former, unless both occur on the same plants, as is frequently the case. The uprolling of the margins of leaflets will usually distinguish tip burn from "late blight." (Fig. 17).

This trouble occurs most seriously during dry weather in midsummer when transpiration of water from the leaves takes place more rapidly than the roots can take in water from the soil. This, of course, results in a drying out of those parts most exposed to the dry atmosphere. The tips and margins of the leaflets are consequently the first to die.

Fig. 18—Net Necrosis. Showing a rather extreme case.

The trouble may be considerably lessened by frequent shallow cultivation of the soil in order to make a dust mulch which prevents evaporation of the soil moisture. Spraying also prevents it to a marked extent under New England conditions.

Internal Brown Spot and Net Necrosis. The internal spotting and streaking of potato tubers is a common trouble in Pennsylvania, particularly in dry seasons. "Net-necrosis" was particularly prevalent in 1914. (Fig. 18).

Fig. 19—Black Heart. Tuber had been pared and cut for cooking.

These troubles appear to be associated with certain soil conditions, such as a lack of potash, and dry weather. While they lessen the value of the crop very materially they are not considered to be dangerous diseases, for such tubers may be planted and produce a healthy crop. The use of such tubers for planting should not be recommended, however, if healthy tubers can be obtained, on account of the possibility of confusing this trouble with certain stages of "wilt" and "stem rot."

Black Heart. This trouble appears infrequently and may be due to several conditions. Perhaps it is encountered most frequently in lots of tubers which have been shipped in cars heated by stoves to prevent freezing. It may also appear in storage pits where sweating or heating has taken place. It is not parasitic.

Hollow Potato. Frequently, tubers are seen which have hollowed centers. This appears most commonly in certain varieties which are overgrown, due to peculiar weather and soil conditions. Unevenness of growth, such as rapid growth the latter part of the season following slow growth, appears to cause it in certain cases. Varieties which tend to this condition should be avoided.

5. Troubles caused by the use of Chemicals.

Arsenical Injury. Paris green frequently causes a dying of the leaves, particularly in spots, and is sometimes confused with "early blight." It usually appears within a few days after Paris green has been applied. This may be prevented by adding lime

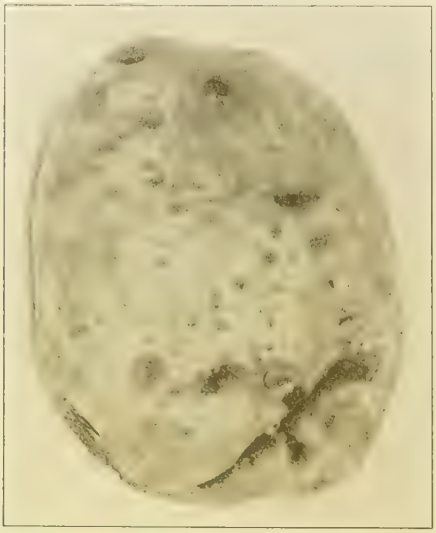

Fig. 20.—Formaldehyde pitting of tubers due to gas adsorption.

to the Paris green; if used as a spray add a pound of lime to the water for each pound of Paris green; if used dry add air-slaked lime at same rate. Paris green mixed with Bordeaux or other sprays will not usually cause damage.

Formaldehyde Injury. When the formaldehyde gas method is used for disinfecting seed tubers, serious injury may result if the

proportion of formaldehyde to cellar space is too great; or if the proportion of tubers to cellar space is too small, as has been outlined under seed disinfection, page 10.

The injury takes the form of brown sunken spots surrounding the lenticels and eyes. (Fig. 20). Germination is much impaired if the spotting around the eyes is noticeable.

6. Diseases of uncertain cause.

Curly dwarf. Under this name a peculiar disorder of potatoes is known in the more northern potato sections from Maine to California and undoubtedly exists to some extent in Pennsylvania.

Acording to Orton[9] diseased plants are "characterized by a dwarfed development of the potato plant, accompanied by a pronounced curling and wrinkling of the foliage." Apparently it may be confused with certain symptoms of the "russet scab" disease. Frequently the diseased plants fail to produce tubers and when tubers are produced they are usually few and not of marketable size.

The disease indicates a run-out condition of the stock and such seed stock transmits the disease when planted. So far as known, the disease does not spread from diseased to healthy plants in the field.

Preventive measures necessitate the "roguing" of all diseased hills during the growing season, in order to avoid any chance tubers, which might be formed, from going to storage and being used for seed the following season.

Leaf roll. This is another disease of apparently similar nature to "curly dwarf," but having different symptoms. In "leaf roll" the margins of the leaves of affected plants roll upward on the midvein, often assuming a tubular shape. Accompanying the rolling there is some discoloration of the leaves varying from yellowish-green to reddish or purplish, the color depending on the varieties.

The disease may appear early in the season or even relatively late in late plantings. The plants are checked in growth and die early. The yield is much reduced and often no tubers are formed

[9] Orton, W. A., Potato Wilt, Leaf Roll, and Related Diseases Bull. U. S. Dept. Agri. No. 64. 1914.

True "leaf roll" like "curly dwarf" is transmitted through the seed tuber. It further acts like "curly dwarf" in that the disease is not spread from diseased to healthy plants. Roguing is the most satisfactory method of eliminating the disease.

It is not likely that "curly dwarf" and "leaf roll" cause more than a very small loss to the potato crop in Pennsylvania, yet care

21 22

Fig. 21—Flea beetle punctures on potato leaf. Some "tip burn" also present.

Fig. 22—Showing effect of Colorado potato beetle on potato leaf.

should be taken, particularly with "leaf roll," to remove the diseased plants during the growing season in order to prevent further loss.

7. Diseases caused by Insects and Rodents.

The potato troubles due to insects are nearly as numerous as those caused by plant parasites, such as the bacteria and fungi.

Some of the insect troubles are fully as severe as any due to other causes and it is thought best to briefly describe and give remedies for the most common of these.

Colorado Potato Beetle, (*Leptinotarsa decimlineata* Say) This insect is one of the most common pests of the potato. The striped beetle hardly requires description and the effect on the plants is also familiar to all potato growers. (Fig. 22).

Early spraying with arsenical poisons is very effective in controlling this pest. Paris green is most efficient but 3 pounds of lead arsenate paste added to 50 gallons of water or Bordeaux Mixture is nearly as effective and does not cause noticeable injury to the foliage. *Make the first application as soon as the first brood hatches.*

Flea Beetle, (*Epitrix cucumeris* Harris) This is one of our most common pests and annually causes considerable damage by eating tiny holes in the potato leaves. (Fig. 21). The adult beetle feeds not only on the potato but on other plants, particularly those weeds related to the potato plant. For this reason and also because it feeds commonly on the under side of the leaves it is especially difficult to control.

Arsenical sprays are not efficient. Bordeaux Mixture acts as a repellant and is the most satisfactory spray yet found for this pest. It must be applied often enough to keep the newly forming leaves covered. If a sprayer is used which will cover the under sides of the leaves the results will be much more satisfactory. Spraying with a high pressure outfit will accomplish this to some extent. Keep down the weeds upon which the beetles also feed.

Stalk-borer, (*Trichobaris trinotata* Say) The "stalk-borer" is a destructive pest of the potato plant in eastern Pennsylvania. The writer saw fields in 1915 where 90 per cent of the plants were infested with this insect. Needless to say it causes much loss in such cases.

While the adult insect, which is a snout beetle, feeds to some extent on the foliage, the chief damage is caused by the larvae which enter the stems usually in July. They bore into the pith and tunnel down the stalk, killing the plant. The larvae are small yellow grubs about one-third of an inch in length with a brownish head. They may be detected in the stalks by splitting the latter

down with a knife. Later in the season the larvae pupate in the stalks and winter over in this condition.

The larvae also infest other plants, particularly horse nettle and ground cherry, and such weeds should be kept down as much as possible.

Inasmuch as the insect lives over winter in the pupal stage inside the dead potato stalks, burning of the old vines in the field is the most satisfactory method of control. This should be done in the fall.

Fig. 23—Field Mice injury on potato tubers. (Illustration by courtesy of C. F. Noll.)

White Grubs, *(Lachnosterma spp.)* The damage to potato tubers by the white grubs is well known. The adult stage is the common June bug, a large beetle which flies at night in May and June. These beetles lay their eggs on the ground, most frequently in sod fields. These eggs hatch out tiny grubs which become full grown in about two years and emerge in the beetle stage about three years after the eggs are deposited.

The methods of control are not as satisfactory as could be desired. Hogs are often turned into infested fields and will clear

the grubs, but such practice is not to be generally recommended because of an intestinal worm of hogs which passes one stage of its life history in certain white grubs. It appears that this is the chief method of infection of hogs with this parasite.

Inasmuch as the most serious injury to potatoes from white grubs usually follows the turning under of grass sod, better results are obtained by following a rotation in which potatoes follow clover or alfalfa, two crops not often infested with white grubs.

Plowing in the fall before the ground freezes, turns up and crushes some of the grubs. Disking the soil after fall plowing will also kill a considerable number.

Some relief may be obtained by setting out pans of water on which coal oil is poured and suspending at night, over these traps, a lantern during the period when the beetles are flying. The beetles, attracted by the light, fall into the pans containing the coal oil, which is fatal to them.

Field mice, (*Microtus* spp. and *Pitymys* spp.) There are several species of these little animals which burrow around chiefly in sod land. They attack a wide variety of field crops, also fruit and shade trees. The potato is one of their favorite vegetables and the damage to this crop by field mice is considerable. The writer has seen in some fields hill after hill with hardly an entire tuber left.

The gnawing by field mice has often been confused with white grub injury, but they may be distinguished from each other by carefully examining the eaten spots. (Fig. 23). The field mice leave quite conspicuous teeth marks, not seen in white grub injury.

The surest method of getting rid of these pests is by thorough cultivation of the soil for the destruction of weeds in the potato field, and the elimination of fence rows which are favorite breeding haunts.

Poisoning is also recommended by Lantz[10]. Several poison baits are used such as strychnine and grain, or strychnine and sweet potatoes but probably the clean cultivation method is about as efficient and the final results more satisfactory.

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[10] Lantz, D. E., Field Mice as Farm and Orchard Pests U. S. D. A. Farmers Bull. 670. 1915.

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